

## SPS SILICON REFERENCE SYSTEM

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The silicon reference SPS is one of two reference designs developed by the NASA Systems Definition Studies, the other being a Gallium Arsenide option. The JSC/Boeing study emphasized silicon and the MSFC/Rockwell study emphasized Gallium Arsenide. These two options provide a balance between a more mature, relatively well-understood photovoltaics technology and a more advanced one which offers performance advantages and possibly cost advantages.

The composite drawing of Figure 1 illustrates the main features of the silicon reference system. The solar array consists of glass-encapsulated 50-micrometer silicon solar cells, interconnected in series-parallel arrangement to provide the necessary voltage and cell failure redundancy. The array blankets are suspended in a space-frame cubic trusswork of 128 bays, each 667.5 meters square and 470 meters deep. A tension catenary system maintains the solar cell blanket in each bay adequately flat, with a "trampoline" natural frequency about twice that of the solar array support structure as a whole. The array area of 49.6 square kilometers generates 8766 megawatts (dc) electric power at 44 kV. This electric power is conducted by an arrangement of ten pairs of power busses to the electrical slip ring interface between the power transmitter. The transmitter converts the electric power to 6700 megawatts of radiated RF power at 2450 megahertz.

Details of the solar blanket are illustrated in Figure 2. The individual solar cells are about 50 square centimeters. The size was selected to be compatible with the electrical arrangement of the solar array depicted in Figure 3 and the number of cells in series (about 77,000) required to deliver the required voltage. The cells are encapsulated in panels roughly one meter square and the panels are interconnected by welded flexible tabs. Each panel incorporates a pair of shunting diodes to protect it from reverse voltage in the event of shadowing. Panels are mechanically interconnected by glass fiber tape and are folded or rolled in shipping containers for delivery to space.

Figure 3 also shows the general scheme for power distribution to the array-antenna interface. Sets of solar cell strings are connected to the satellite main busses at the 2000-amp level through sets of switchgear to provide fault protection as well as isolation of strings of cells for annealing. The main busses are 1-mm aluminum. Passively-cooled conductors of this nature become lighter as they are made thinner. The 1-mm figure provides reasonable minimum gauge and conductor width. The conductors are supported below the solar array by secondary structure.

Silicon solar cells degrade in the space environment as a result of ionizing radiation. The principal source of damage is solar protons from flare events. Prediction of the amount of degradation is complicated by the statistical nature of flare phenomena as well as by problems in extrapolating available proton spectral data to the 2 to 10-MeV energy range that will cause most of the damage. There is also some uncertainty in the amount of degradation to be expected at any given fluence as well as uncertainty in converting from test results (usually isoenergetic) to the solar proton spectrum. The Boeing studies used a generally pessimistic radiation model (more fluence than the expected value) and measured proton damage data for experimental 50-micrometer cells. The result was an estimate of 30% output loss for the silicon satellite at the end of a 30-year "book life" period. The reference system therefore includes an in-situ annealing system that would be used every few years to restore array performance. Characteristics of the annealing system were based on extrapolation of results of preliminary experimental laser annealing of proton-damaged 50-micrometer solar cells.

The interface between the solar array and transmitter consists of a support yoke, a mechanical turntable drive, and an electrical slip ring. The overall yoke arrangement was depicted in Figure 1. Figure 4 shows additional detail of the electrical slip ring. Twenty rings provide conductor paths for the ten pairs of busses. The slip ring diameter was minimized to the extent practicable considering the currents to be delivered, clearance for bus connections, and thermal control. The slip ring size allows it to be assembled and checked out on the ground and delivered to orbit intact aboard the reference Heavy Lift Launch Vehicle.

The power transmitter includes 101,552 high-efficiency Klystron power transponders each including phase control equipment and power control and data management support systems. The transponders conjugate and amplify the uplink phase control signal from Earth and return it to the point of origin as a power beam. Each klystron is individually phase-controlled to maintain precision beam control and high gain. Three levels of control are provided for beam steering: (1) Coarse mechanical pointing of the antenna by the turntable drive; (2) Fine mechanical pointing by antenna-mounted CMG's; (3) Ultra-fine electrical pointing by the phase control system. The CMG's are continuously desaturated by the turntable drive; the overall angular momentum control for the satellite is provided by electrical thruster systems at the four corners of the solar array.

The antenna power intensity is tapered over the aperture to provide high power transfer efficiency and low sidelobes. The taper ranges from a maximum of 22 kw per square meter at the center of the antenna to 1/9 of this value at the edge, as schematized in Figure 5. The Klystron transponders are assembled into subarrays 10.4 meters square. The subarrays include the slotted waveguide radiators, distribution waveguides, thermal control equipment, phase control equipment, support structure, and data and control systems. They are designed to be assembled and tested on the ground prior to shipment to space. Most of the electronic complexity of the power transmitter is within the subarrays, thus most of the electronic integration can be done on Earth.

Power supplied to the Klystrons must be partially processed. About 85% of the power can be provided unconditioned from the solar array with only breaker protection. The balance is processed by substations located at the back of the power transmitter. Figure 6 is a preliminary concept of such a substation. The size of the individual processors was selected so that outage of a single processor (and the Klystrons it supplies) will not significantly disturb the power beam pattern.

Satellite configuration control and data management are provided by a triply-redundant communications system interconnected with a redundant, hierarchical, distributed-processing computer network. Triple redundancy of computers is also provided for critical functions such as flight control. All data and communications interconnects employ fiber optics in order to minimize interference from the satellite electrical and RF power systems.

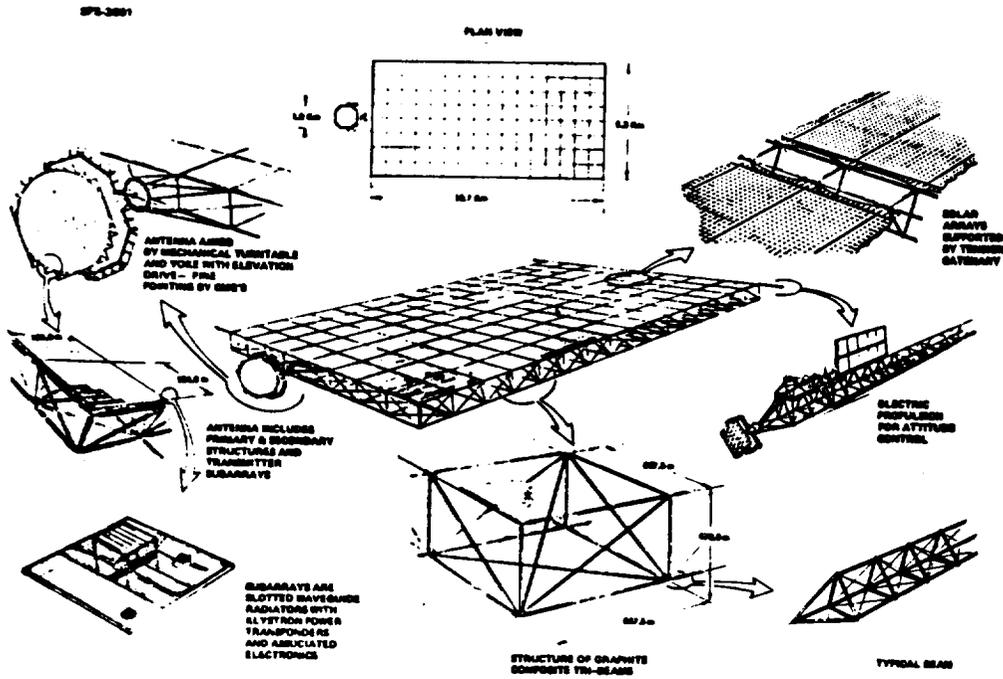


Figure 1- SPS SILICON SOLAR ARRAY REFERENCE DESIGN CONCEPT

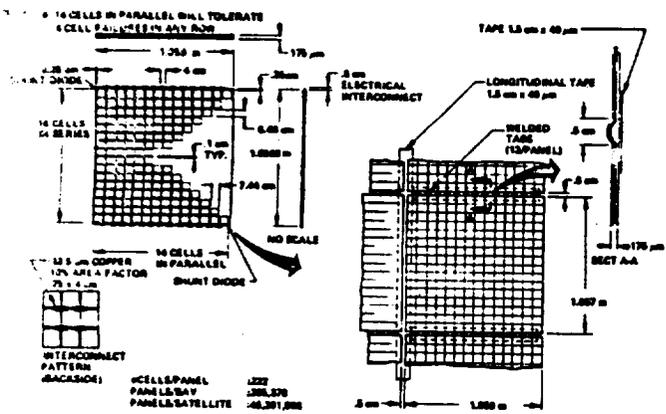


Figure 2- REFERENCE PHOTOVOLTAIC SYSTEM DESCRIPTION

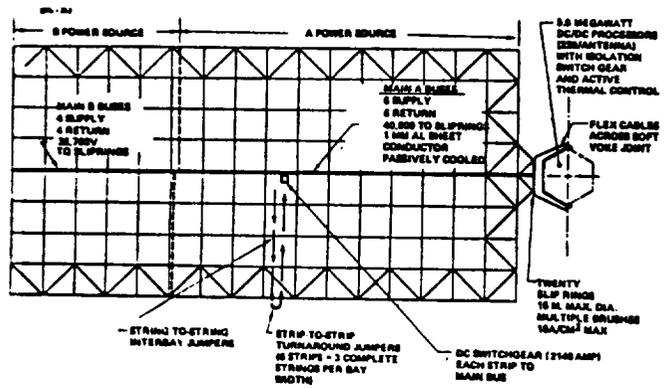


Figure 3- MULTIPLE BUS SPS POWER DISTRIBUTION

ORIGINAL PAGE IS  
OF POOR QUALITY

● SEVERAL COMPONENTS REQUIRE PRODUCTION RATES GREATER THAN PRESENT CAPABILITY

- SOLAR BLANKETS
- GRAPHITE STRUCTURE
- KLYSTRONS
- ELECTRIC THRUSTERS
- LIQUID HYDROGEN

● ONLY SOLAR BLANKETS REPRESENT A PROBLEM

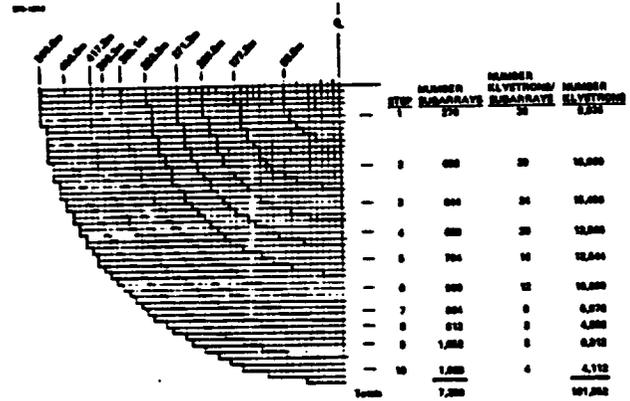


Figure 4- INDUSTRIAL INFRASTRUCTURE

Figure 5- MPTS REFERENCE POWER TAPER INTEGRATION

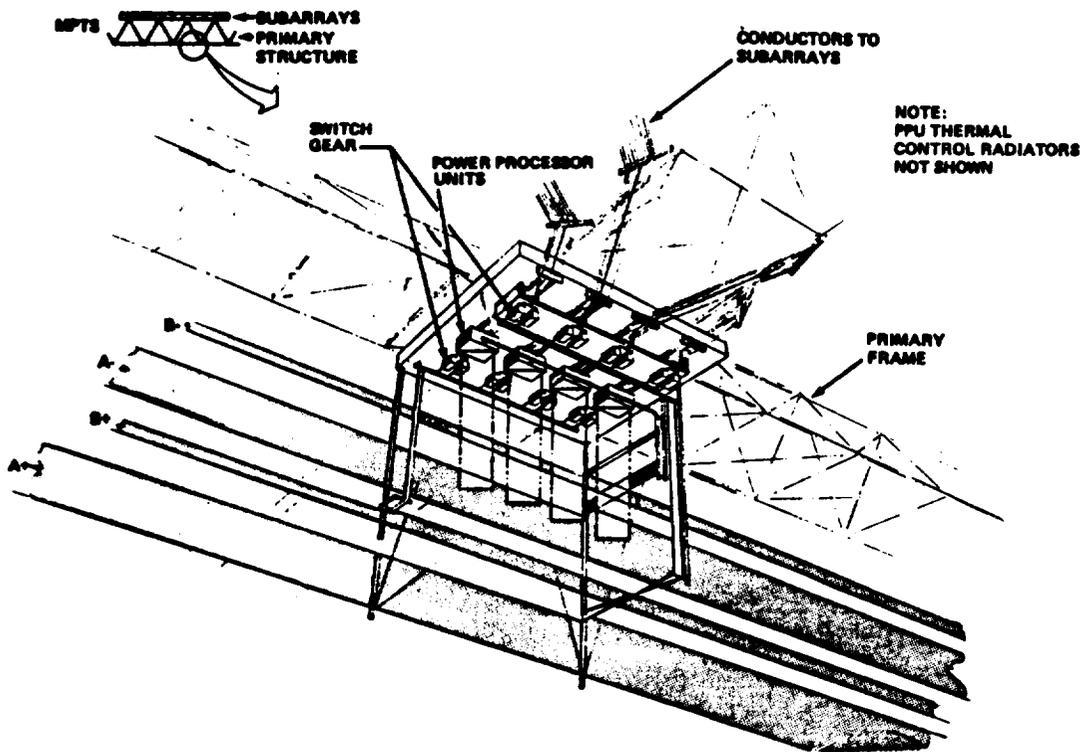


Figure 6- MPTS POWER PROCESSING SUBSTATION